

# Modern Concepts of Cardiovascular Disease

Published monthly by the AMERICAN HEART ASSOCIATION

50 WEST 50TH STREET, NEW YORK, N. Y.

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Vol. V

February, 1936

No. 2

## THE DEVELOPMENT OF THE HEART

### Part II

#### DIVISION OF THE HEART

##### THE ATRIOVENTRICULAR CANAL

The primitive cardiac tube is narrowed between the dilated atrium and ventricle; this is the atrioventricular canal which after folding of the tube is directed, for the most part, dorso-ventrally. In the canal appear two thickenings of the subendocardial tissue, the *endocardial cushions*, which project into the lumen from ventral and dorsal aspects and which by their fusion in the mid-line form a septum, the *atrioventricular septum*. The septum divides the canal into right and left atrioventricular orifices. Before subdivision is complete other smaller cushions, right and left, appear. From these and from the margins of the centrally placed atrioventricular septum, the valves (mitral and tricuspid) guarding the orifices will appear.

##### THE SINUS VENOSUS

The sinus venosus, the first chamber of the primitive heart, exhibits two horns, right and left, into which are received the openings on either side, of the paired vitelline and umbilical veins and the ducts of Cuvier. As mentioned in Part I, the sinus lies initially in the septum transversum but with further development of the heart is projected into the pericardial cavity. Associated with this projection and with the expansion of the atrium, the right horn of the sinus venosus is invaginated into the atrial cavity. In consequence the opening between these two chambers is displaced to the right and the invagination brings about the formation of *right and left venous valves*, which guard the opening for a time and prevent regurgitation of blood during systole of the heart.

The right horn of the sinus venosus and its opening into the atrium undergo progressive enlargement, giving rise to the larger part of the right atrium. The original atrium is pushed further and further forward by the expansion of the sinus and its cavity is eventually represented by the auricle (auricular appendage) alone. The sulcus terminalis of the fully developed atrium marks the junction between the two primitive cavities.

The right venous valve persists in some measure as the valve (Eustachian) of the inferior vena cava and the valve (Thebesian) of the coronary sinus.

The left venous valve is thrust against the developing interatrial septum, degenerates, leaving a few remnants.

The left horn of the sinus venosus persists as the coronary sinus and the left duct of Cuvier as the small oblique vein of Marshall on the dorsal surface of the left atrium.

##### THE INTERATRIAL SEPTA AND THE ATRIA

Division of the primitive atrium into right and left cavities begins with the appearance of a septum, the *septum primum*. This septum, arising as the result of unequal expansion of the two halves of the atrium, appears as a crescentic fold on its cephalic wall. It extends downwards and forwards on the dorsal and ventral walls to reach the respective cushions of the atrioventricular canal. Dorsal to the endocardial cushions, between them and the free edge of this septum, there exists for a time an interatrial communication, the *foramen primum*. This foramen is soon obliterated with the deepening of the septum and the fusion of its free edge with the enlarging atrioventricular cushions. Before the foramen primum is totally obliterated a second interatrial opening, the *foramen secundum* or *ovale*, appears in the dorsal part of the primary septum, the outcome of a local growth failure.

A little later a secondary septum, the *septum secundum*, develops to the right of the *septum primum*. This septum seems to appear simultaneously from the dorsal wall, roof, and ventral wall of the atrium. Its dorsal portion lies to the left of the left venous valve with which it intimately blends. The septal edge thickens and arches over the atrial roof to the right of the foramen secundum. Its extremities blend with the septum of the atrioventricular canal. This thickened edge is the future *limbus fossae ovalis* (annulus ovalis).

The right atrial cavity with the exception of its auricle (auricular appendage) is developed, as discussed above, by expansion of the right horn of the sinus venosus. The cavity of the left atrium arises in a somewhat similar manner. The primitive left atrial cavity receives at first a common pulmonary vein which opens in close proximity to the septum primum. The cavity increases at the expense of this vein and its right and left branches which by expansion are absorbed into the atrial wall. This process of pulmonary vein absorption extends as far as the upper and lower branches of its right and left divisions. As a consequence the four pulmonary veins come to open into the left atrial cavity, independently, at its four angles. Associated with this expansion, the original cavity is projected further and further forward about the roots of the great vessels and is represented in the fully developed heart by the auricle (auricular appendage) alone.

#### THE INTERVENTRICULAR SEPTUM, THE VENTRICLE AND BULBUS CORDIS

Separation of the common ventricular chamber into right and left cavities occurs in part in a manner not dissimilar to the division of the common atrium into right and left halves. Expansion and growth on either side of the mid-line results in the formation of a septum which consists of the thickness of the ventricular wall, the *pars muscularis* of the *interventricular septum*. The semilunar septum extends from the lower dorsal atrioventricular cushion below, to the upper ventral cushion above. It passes close to the junction of bulbus cordis and ventricle so that with the appearance of this septum the bulbus cordis is related for the most part to the right half of the ventricular chamber. Behind and above the free edge of the septum the two cavities communicate for a time, the *interventricular foramen*.

The adjacent walls of the bulbus cordis and ventricle fuse and atrophy. This atrophy involves mainly the left wall so that the arterial cushions, which have appeared in the truncus arteriosus, come to be in close relationship to those of the atrioventricular canal. The cavity of the bulbus is in large measure the infundibulum of the right ventricle.

In the meantime other changes related to the separation of right and left ventricle are occurring in the bulbus region. There extend from the arterial cushions in the distal part of the bulbus two ridges, the *right and left bulbar ridges*, arranged in spiral fashion, one on either side. That on the right side extends down the right wall to the region of the right atrioventricular orifice. That on the left extends along the left and ventral wall reaching to the interventricular septum. Fusion of these swellings or ridges with one another and with the interventricular septum forms the *pars membranacea* of the septum and completes the separation of right and left ventricular cavities. Behind and to the left of this part of the septum, is shut off that channel leading from the left ven-

tricular cavity to the future aorta known as the *aortic vestibule* which has, therefore, arisen in part from the bulbus and rendered more extensive by atrophy of the bulboventricular junction.

#### THE INTERARTERIAL SEPTUM AND TRUNCUS ARTERIOSUS

Division of the truncus arteriosus and more cranial part of the bulbus into the root of the aorta and pulmonary artery occurs by the formation of a septum, the *interarterial septum*, derived from several sources. In the more cranial part of the bulbus appear four swellings or arterial cushions. These are disposed on the right and left lateral, on the dorsal and ventral aspects. Of these the right and left are the larger and are continuous caudally with the right and left bulbar swellings respectively. Fusion of the more prominent lateral cushions with one another creates an interarterial septum which continues the spiral arrangement of the bulbar septum into the arterial trunk.

At the junction between the fourth and sixth arches which give rise to the trunks of aorta and pulmonary artery respectively, a second septum, the *aortopulmonary septum*, appears which extends caudally and by fusion with the interarterial septum completes the division into aorta and pulmonary artery. The continuous septum derived from the bulbar ridges, interarterial and aortopulmonary septa extends down as a right-handed spiral, its right border above, becoming first dorsal, then left lateral and finally ventral, below. As a result, the blood from the right ventricle is directed into the sixth pair of arches, the pulmonary arteries, and that of the left into the fourth and remaining arches which will give rise to the main arterial trunks.

On the left side the fourth arch is converted in the arch of the aorta; that at the right constituting at its root the innominate artery and its arch the right subclavian artery. The ventral parts of the sixth pair of arches persist as the right and left pulmonary arteries. The dorsal part on the right atrophies whilst that on the left persists up to birth as the *ductus arteriosus* connecting, therefore, with the dorsal aorta.

The fifth pair of arches makes but a very transitory appearance.

Later during intra-uterine life, after separation of the arterial trunk into aorta and pulmonary artery, a further rotation of the heart to the left carries the root of the pulmonary artery more definitely to the front and left of the aorta, the right ventricle occupying largely the anterosuperior surface of the heart, the left, the postero-inferior position.

The arterial cushions, ventral and dorsal, and portions of the right and left lateral, finally are developed into the semilunar valves, three guarding each orifice.

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